

Managing R&D Collaboration as Virtual Organization

— A Suitable Concept?

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Abstract: Facing a growing number of R&D collaboration in the Triple Helix (TH) context I analyzed the relevance of the virtual organization (VO) concept and the transferability to real R&D collaboration. My analysis on 291 published research articles connected to VO and 86 articles on virtual teams (VTs) provided insights to the actual research situation in this area. Furthermore I analyzed and structured 34 different definitions of VO. The structuration of attributes based on the four characteristics developed by DeSanctis and Monge (1999). 87 different attributes demanded for an expansion to six attributes. Consequently VOs are defined as (1) geographically distributed, (2) electronically linked, (3) functionally or culturally diverse, (4) laterally (versus hierarchically) connected, (5) represented as one, and (6) goal-oriented. Transferring these characteristics of a real R&D collaboration to the TH context proves the applicability of the VO attributes to R&D collaboration. This paper contributes at clarifying the term of VO, depicts the relevance for the R&D context and offers options for future research.

Key words: virtual organization; R&D collaboration; university-industry-government; research management; virtual team

JEL codes: O32, M100, M150

1. Introduction

The numbers of research and development (R&D) collaboration have grown tremendously in the last ten years (for example see BMBF, 2010). In Germany, research partnerships between companies and universities or private research partnerships have grown about 25% annually between 2002 and 2008 (ZEW, 2011). Due to the diversification or even hyperspecialization (Malone et al., 2011) of the partners, those collaborations are formed over geographic distances, cultural and institutional differences. This requires new organizational structures and management methods and needs to be better defined and researched (Gassmann & Zedtwitz, 1999; Kirkland, 2005). For doing this, a proper definition of the organizational form is essential. These new organizational forms play a role outside the intensively researched private sector, too. Hence, this paper will have a special focus on R&D cooperation of different partners (e.g., between university, industry and government, so-called Triple Helix (Etzkowitz & Leydesdorff, 2000; Etzkowitz, 2008)).

Virtual organization (VO) is a “buzzword” of the twenty-first century and the discussion about the

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characteristics of VOs is as old as the discussion about the clear definition of it (Kasper-Fuehrer & Ashkanasy, 2003). Even though heterogeneous definitions and concepts in a large number of publications exist, a common understanding or a consistent concept of virtual organization is still missing (Kotorov, 2001). A systematic analysis of 34 different definitions of VO will show that numerous definitions are not as different and exclusive as some of them perhaps would like to be. This will help as contribution to the clarification of central characteristics of VOs. Additionally, this clarification will help managers in identifying VOs.

Purpose of this paper on the one hand is to show, whether the VO concept is still an up-to-date, interesting and relevant research topic and to provide insights into existing research gaps. This will include a quantitative analysis of 291 articles recently published in this field as well as a quantitative and qualitative contribution on clarifying the attributes of VO. As research on virtual teams (VT) is closely connected to research on VO, another literature review of 86 articles on VT will be added. On the other hand, the second objective is the testing of the continually developed definition of VO (based on the analysis of 34 existing definitions of VO) and its transferability to a real R&D collaboration.

The paper is structured as follows: After presenting a brief overview of the literature on VO and VT connected to R&D collaboration, the research questions will be elaborated. The methodology paragraph will be subdivided referring to the two research questions, and the same counts for the results paragraph provided afterwards. Lastly, the new and expanded attributes of VO are transferred and applied to a real R&D collaboration case, and a discussion closes the paper together with a conclusion and implications for R&D management.

1.1 Brief Overview on VO and VT Connected to R&D Collaboration

A search within the database “Web of Knowledge” for the most frequently cited articles (total citation at least 20 since 1996) identified 45 articles using “virtual organization” as topic. Those articles focused mainly on trust aspects within VOs (Handy, 1995; Gallivan, 2001), communication aspects (Ahuja & Carley, 1999; Wiesenfeld et al., 1999), identification aspects (Thatcher & Zhu, 2006), structuring and “building” VO (Ching et al., 1996; Barry & Elmes, 1997; Magretta, 1998; Strader et al., 1998; Djelic & Ainamo, 1999; Hernes, 2004; Afsarmanesh & Camarinha-Matos, 2007) and GRID optimization (Alfieri et al., 2005; Andreozzi et al., 2005; Laganà et al., 2006). A search refinement to “R&D” resulted with no answer. A repeated search refinement with “innovation” answered with four articles. The most famous article in this area, written by Chesbrough and Teece (1996) and reissued in 2002 (Chesbrough & Teece, 2002), provides a framework for determining the right organizational form depending on, e.g., the type of innovation. This frame is an overall frame; hence, the applicability on R&D collaboration in the university-company environment still lacks some evidence. The remaining two articles miss a relevant connection to R&D collaboration as focused within this paper.

Coming to literature on virtual teams, central aspects of the most cited articles deal with trust (Jarvenpaa & Leidner, 1998, 1999) and its antecedents (Jarvenpaa et al., 1998), effectiveness and performance (Maznevski & Chudoba, 2000; Ahuja et al., 2003; Jonsen et al., 2012) knowledge exchange and communication (von Krogh et al., 2003; Kirkman et al., 2004) and leadership aspects (Kayworth & Leidner, 2000; Bell & Kozlowski, 2002; Kayworth & Leidner, 2002). For this paper, the definition from Powell et al. (2004) will be used who defined virtual teams as groups of geographically, organizationally and/or with regard to their working hours dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks (DeSanctis & Poole, 1997; Jarvenpaa & Leidner, 1999) on an “as needed basis” to cooperate task-oriented on specific deliverables, or to fulfill specific customer needs (Lipnack & Stamps, 1997). Obviously, literature on virtual teams focuses rather on the individual and team member level than on organizational

characteristics, which are the focus of this paper. Nevertheless, relevant research topics here are also of interest for VO research and, hence, part of this qualitative literature overview which contributes to providing an actual picture of research on VO and VT.

First conceptual works combining R&D management and the virtual organization concept have been published in 1998 (Lewis, 1998; Adler & Zirger, 1998). Both contributions have rather been written from a neutral or a company's perspective. Adler and Zirger (1998) rather analyze the facilitation of organizational learning within a virtual R&D organization. Lewis (1998) investigates the successful sharing of knowledge — eventually supported by information and communication technology (ICT) — and emphasizes again the importance of trust as already mentioned by Handy (1995). Weisenfeld et al. (2001) show with their case-based article, that building trust and commitment lowers the cost of coordination and motivation. This contribution together with the article from Gassmann and Zedtwitz (2003), structuring trends and determinants of managing virtual R&D cooperation, again just point out the topic from the company's perspective. But managing R&D in the university environment at the moment somehow lacks proof of transferability of these concepts.

2. Research Questions

The research field on Virtual Organization and related topics was started more than 20 years ago, powered by the developments in the information and communication technology and the trends of focusing on core competences and related outsourcing (Heneman & Greenberger, 2002). Being aware of already existing literature reviews on this topic (e.g., focusing on small and medium-sized enterprises (Pihkala et al., 1999) or e-Science (Andronico et al., 2011)), a contribution which provides an overview of the research and closes the gap of a missing clarification of VO attributes (Kasper-Fuehrer & Ashkanasy, 2003) is still missing, especially from the R&D collaboration point of view. Thus, the first research question (RQ) is:

- (1) Is the VO concept still up-to-date and relevant?
 - (a) What did the recent research on VO and VT focus on?
 - (b) Has the definition of VO continuously been evolving in the last ten years?

Even though the concept of VO has been researched from the R&D point of view (e.g., for structures of virtual R&D projects see Gassmann and Zedtwitz (2003), for the pharmaceutical industry see Chiesa and Manzini (1997)) the transferability of the update VO concept into a real R&D collaboration case — especially in the Triple Helix (TH) environment is missing. For this reason our second research question is:

- (2) Is the up-to-date VO transferable to a real R&D collaboration in the public or mixed (Triple Helix) context?

3. Methodology

3.1 Is the VO Concept Still Up-to-Date?

In order to answer this first wide question, the aspect was advanced from two different perspectives. First, an intense Scopus database query was conducted and several factors were analyzed in order to identify the most researched and recent relevant topics in this field. Second, I will analyze and structure 34 identified definitions of VO in order to consolidate the range of VO definitions and develop core attributes of VO.

3.2 Data for Recent Research on VO and VT

In order to gain an overview of the recent research, two queries within the Scopus database searching within

title, abstract and keywords were conducted from January 1st 2010 till September 15th 2011 using “virtual organization” and one query from January 1st 2012 till August 29th 2014 with the term “virtual teams”. From the “virtual organization” query, 291 articles resulted. For the “virtual team” query, several hundred articles have been identified. Because of the special focus, abstracts were screened and only papers relevant for the international and R&D context have been investigated. This resulted in a number of 86 articles and book chapters. In order to identify where the latest research on this topic took place, and in which context this happened, several criteria for structuring the articles have been chosen. The titles, abstracts, key words and affiliations of authors have been analyzed based on the following criteria:

- Country of first author (based on the affiliation named in the publication)
- Research method (conceptual, longitudinal, review or case-based)
- Sector focus of the paper (company, university, neutral)
- Geographic focus of the paper (national, international)
- Kind of publication (journal, proceedings, book).

Through the quantitative data, I will provide a relative frequency analysis in order to get an overview of the recent research in this field.

3.3 Data for Overview of VO Definitions

In order to understand whether the definition of VO has further developed in the last twenty years, 34 different definitions were analyzed. Data for providing an overview on definitions of VO was gained from several sources. Google, Google Books, Google Scholar and the Scopus and Ebsco databases using “define ‘virtual organization’” were screened for relevant articles including definitions for VOs. All the definitions have been split up into a total of 102 attributes. I removed double named attributes and finally received 87 attributes. I started structuring the attributes based on the characteristics developed by DeSanctis and Monge (1999) as this structure is based on an already existing summary of attributes developed in 1999. They highlighted, that these attributes can be applied to VT, too. The attributes as component entities of virtual organizations are: (1) geographically distributed, (2) electronically linked, (3) functionally or culturally diverse, and (4) laterally (versus hierarchically) connected. The 87 attributes excerpted from the VO definitions were assigned to these attributes as far as possible, nevertheless two more attributes had to be added: “represented as one” and “goal-oriented”.

3.4 Transferability of VO to a Real R&D Case

Gaining insights into the practical relevance of the VO concept and VT literature to a virtual R&D collaboration was the second central objective. The case of a TH cooperation which includes partners from university, industry and government will be presented. In order to test the applicability of the attributes developed from the analysis of definitions, this real R&D cooperation will be used as a first reference point.

4. Results and Findings

4.1 Results of Recent Research on VO

The frequency analysis of the research in the recent 20 months on virtual organization provides an interesting overview of the following criteria (for more details see tables in the appendix):

Which country is very active in publishing?

Concerning the relative frequency of “country of first author” in research publications on VO referring to the mentioned affiliation, all countries with at least 10 publications in the relevant period were rated. 21.6% of the

first authors were Chinese. 14.8% of all first authors were classified as US Americans. This was followed by the first author's locations Spain (8.2%), Italy (6.5%), Germany (5.5%) and United Kingdom (4.1%). 44 different nations could be identified as country of first author. This data has to be considered in relation to the whole population of the particular nation, but I gained an overview of where the actual research takes place. First authors from these six countries contributed 60.7% of the most recent research in this field. Nevertheless I observed an international relevance of this topic due to its broad application. Recent literature on VT was mainly written by authors or groups with the first author from the US or the UK, followed by Germany, Australia and Taiwan. About two-thirds of papers relevant to VTs have been published by authors located in these countries. 28 different first author's locations have been identified. Interestingly, different to the literature on VO, Chinese or Asian authors are obviously less present in this field.

Which research methods have mainly been used and seem to be appropriate?

Recent research was conducted in different forms (case-based, longitudinal, conceptual study and/or as a review). It is remarkable that — though multiple choices were possible — only two articles were allocated as case-based and longitudinal or case-based and conceptual referred to the VO literature. No abstracts have been available for two articles which, thus, could not have been allocated. At least every second article provided recently was written as conceptual paper (57.4%). I also found a remarkable number of case-based papers (29.2%). Every tenth article could be classified as review. The lowest relative frequency could be found with longitudinal studies (4.5%). The high number of conceptual papers shows that even after 20 years of research on virtual organizations, there is still a need, respectively interest, for further developing the VO concept as otherwise those conceptual articles wouldn't have been written and published. When it comes to literature on VT, almost half of the screened items had conceptual characteristics whereas the other half was based on real data from, e.g., cases. The relatively low number of reviews can be explained with a relatively high number of profound reviews which existed already before (e.g., Hertel et al., 2005; Martins et al., 2004; Powell et al., 2004).

Which geographic focus can be derived?

90.8% of the VO papers focused on and dealt with an international environment. On the one hand, this high score of relative frequency could be explained with the aspect that an international focus already includes a national scope. On the other hand, the globalization of markets and related international collaboration as one driver of VOs (Picot et al., 2003) are accordingly relevant and internationally focused. Results could be of higher relevance for the interested community. Comparing the results of VTs is quite interesting, as this literature — even though queried 2 years later — shows the highest rate in international focus, too, but a very high rate of literature focusing on national VTs and a geographically neutral perspective as well.

Which sector focus is of special interest?

Coming to the relative frequency of the focused sector as research environment, the major part (66.0%) of articles on VO and articles on VT (51.2%) have been held quite neutral. These papers contributed to the VO concept from an organizational point of view. The second largest group focused on VO from the company's point of view (26.2%) (almost the same for literature on VT). 6.9% of the screened articles on VO investigated this topic from a university's point of view. One article combined a university's and a company's perspective. One article provided a library point of view and one article focused on governmental aspects. The neutrality of sector focus goes along with the stated focus on conceptual contributions. Nevertheless, being aware of the growing number of R&D collaborations also between universities, government and companies, it seems worth deeper investigating the suitability and transferability of the VO concept in the TH environment. Coming to literature on

VT, it seems that recent literature presents evidence from universities background and perspective.

Which form of publication has been used?

The last criteria deals with the relative frequency of kind of any publication to get an impression on the most recent research on VO. Almost every second publication was published in form of a journal article (47.8%). For recent literature on VT, this number is even higher (60.5%). 34.4% of the VO articles have been published within conference proceedings, and 17.8% have been published as or within a book. The overall number of identified publication channels used was 180 for VO. So, there were 180 different journals, conferences and books dealing somehow with VO. This again shows the broad interest but also the applicability of VOs in various research fields.

The analysis of these 291 papers generated several key findings. VO topics are researched from authors from 44 different countries. This allows the conclusion that the VO topic is still up-to-date and of international interest. Over 60% of the first authors came from China, the USA and four European countries referring to their specified affiliation. A lot of recent research focused on conceptual and theoretical work. So, there is still need for further investigating into this topic, as the elaborated concepts have to be researched, e.g., for their applicability. Research in the VO area focuses mainly on international studies. This was not surprising, but it is remarkable that more than 90% of the recently published papers have an international scope. Concerning the sector, it was obvious that findings in the university sector and especially in the TH environment are less considered than from the company's point of view. The main part of the 291 studies has been published within proceedings and journals. Nevertheless, the high number of 180 different publication channels (proceedings, journals, etc.) shows that the VO topic is relevant to many research fields. Comparing this to the literature on VT, the findings are even supported as the high journal article frequency (60.7% of VT literature was published in journals) and the high frequency of published conceptual papers prove the relevance of this topic of geographically dispersed organizational entities whose number is still growing. The small number of publications with a special focus on TH and R&D collaboration highlights the existing research gap.

4.2 Structure of 34 Definitions of VO

Through literature studies, 34 different definitions of VO could be identified. The 87 excerpted attributes of the definitions could be largely assigned to the highly cited attributes developed by DeSanctis and Monge (1999): (1) geographically distributed, (2) electronically linked, (3) functionally or culturally diverse and (4) laterally (versus hierarchically) connected. Dedicated attributes are presented in tables and a list of dedicated authors is included. Nevertheless, I found numerous attributes that did not fit in those four characteristics. For this reason, two further attributes needed to be added: (5) represented as one and (6) goal-oriented. The following tables present the excerpted characteristics from the relevant authors and how terms are assigned to the defined attributes.

Table 1 Attributes Classified as “Geographically Dispersed”

7 different attributes excerpted from 34 definitions of VO	Corresponding Authors
work across space	
work across time	
decentralized	
geographically apart/distributed/dispersed	Bleecker (1994), Clancy (1994), Barner (1996), Hedberg et al. (1997), Ahuja and Carley, (1998), Bultje and Wijkt (1998), Robey et al. (2003), Cueni and Seiz (1999), DeSanctis and Monge (1999), Hoeffling (2003), Gallivan (2001a), Gassmann and Zedtwitz (2003), Travica (2005), Stoica and Ghilic-Micu (2009)
independent of any spatial connection	
members never meet face-to-face	
regardless of location	

Attributes classified to the aspect of VOs characterized by the unities being “geographically dispersed” are summarized in the following Table 1. I subsumed all aspects related to geographic distance in this group. The aspect of geographic distance was more often mentioned in the 1990s than in the 2000s, but it still can be seen as one core attribute describing VO as 47.0% of all screened definitions explicitly include the geographic aspect.

Table 2, given below, includes all the aspects that have been named within the 34 definitions of VO and could be classified under “electronic linkage”. 41.2% of the VO definitions explicitly included ICT-related aspects. Due to the geographic distance — as mentioned before — ICT is the only way to guarantee communication and knowledge exchange. Thus, this attribute of VO can also be confirmed as one of the core attributes describing VO.

Table 2 Attributes Classified as “Electronically Linked”

11 different attributes excerpted from 34 definitions of VO	Corresponding Authors
communicate through IT	Byrne et al. (1993), Mowshowitz (1997b), Travica (2005), Ahuja and Carley (1998), Bultje and Wijk (1998), Burn and Barnett (1999), DeSanctis and Monge (1998), Robey et al. (2003), Cueni and Seiz (1999), DeSanctis and Monge (1999), Gallivan (2001), Kasper-Fuehrer and Ashkanasy (2001), Oliveira and Rocha (2001), Gassmann and Zedtwitz (2003)
communication technology	
cooperation based on IT	
coordination through IT	
linked by electronic form of communication	
linked by IT	
links strengthened by communication technologies	
links strengthened by information technologies	
working via computer/e-mail/groupware	
electronic linking	
electronic networking	

Coming to the aspect of the VO entities being “functionally & culturally diverse”, lots of related expressions could be excerpted from the 34 definitions of VO. The numerous terms for this diversity are shown in Table 3. Diversity is a crucial aspect for VOs as it realizes the idea behind: using and combining just the necessary and specialized partners. The independency and autonomy of each partner often is highlighted within some definitions (e.g., Byrne et al., 1993; Travica, 2005). This aspect of diversity is included in 35.3% of the VO definitions and still is a central aspect of VO.

Table 3 Attributes Classified as “Functionally & Culturally Diverse”

13 different attributes excerpted from 34 definitions of VO	Corresponding Authors
competences distributed among a number of distinct operation entities	Byrne et al. (1993), Arnold et al. (1995), Travica (2005), Burn and Barnett (1999), Cueni and Seiz (1999), DeSanctis and Monge (1998), DeSanctis and Monge (1999), Gallivan (2001), Kasper-Fuehrer and Ashkanasy (2001), Gassmann and Zedtwitz (2003), Norman et al. (2004), Vasconcelos et al. (2007)
culturally diverse	
each with a range of problem solving capacities at their disposal	
each with a range of resources at their disposal	
functionally diverse	
composed of a number of semi-independent autonomous entities	
independent companies/ institutions/entities	
independent legal entities/autonomous agents	
individuals, groups, organizational units or entire units	
independent suppliers, customers, even erstwhile rivals	
number of distinct operating entities	
group of people and sub-teams	
participant equality	

The last attribute named by DeSanctis and Monge (1999) dealt with the “lateral connection” and some kind of structural aspects. I subsumed 26 different aspects in this group (see Table 4). This — next to the fact that 61.8% of the VO definitions included this aspect — shows the interesting “debate” on appropriately describing the organizational relation between the partners. Due to the virtuality of the VO, there will probably never exist an ideal or standard structure of such an organization. Here, the attribute of a lateral (non-hierarchical) connection could be confirmed and strengthened as core attribute of a VO.

Table 4 Attributes Classified as “Laterally (vs. Hierarchically) Connected”

26 different attributes excerpted from 34 definitions of VO	Corresponding Authors
changing participants	
coming together quickly (swiftly)	
flexible arrangement	
managed via teams that are assembled and as such assembled according to needs	
no vertical integration	Byrne et al. (1993), Bleecker (1994), Coyle (1995), Arnold et al. (1995), Grenier and Metes (1995), Hedberg et al. (1997), Lipnack and Stamps (1997), Travica (2005), Burn and Barnett (1999), DeSanctis and Monge (1998), Fisher and Fisher (1998), Robey et al. (2003), Sieber and Giese (1998), Cueni and Seiz (1999), DeSanctis and Monge (1999), Hoefling (2003), Gallivan (2001), Kasper-Fuehrer and Ashkanasy (2001), Oliveira and Rocha (2001), Gassmann and Zedtwitz (2003)
not constrained by legal definition of a company	
reconfigurable structures	
team's boundaries vary with the specific project requirements	
Participation may be temporary for some members/ temporary character	
temporary	
temporary or permanent	
alliance	
any institutionalized form of the ability	
collaborative network of people/ or companies	
contractual relationships among entities	
contributed by multiple organizations	
formed in an informal manner	
may exist both within and between organizations	
network	
non-hierarchical	
numerous external ties	
systematic, dynamic and flexible	
task, project or permanent organization	
transcend conventional organizational boundaries	
work across organizational boundaries	
interaction through interdependent tasks	

The next two attributes had been developed in order to structure the excerpted 30 phrases which did not fit in the four attributes which have been developed by DeSanctis and Monge (1999).

Coming to this attribute of “represented as one”, I think that this 5th attribute to VO is necessary, in order to highlight its existence and the outside representation. The lateral connections with the internal view combined with the “external representation” are crucial aspects for virtuality. The terms “appear” and “edgeless” or “permeable” illustrate the flexibility that exists within a VO and which is also crucial to it. Often, there is rather a virtual existence (e.g., in the internet) but no building or location which can be perceived as center. Additionally, borders or structures can hardly be identified. The following Table 5 summarizes the phrases provided within 23.5% of the 34 definitions of VO. Hence, this aspect will be added as core characteristic of VO.

Table 5 Attributes Classified as “Represented as One”

	Corresponding Authors
8 different attributes excerpted from 34 definitions of VO	
no physical presence/company without walls	
borders and structure are hidden	
neither central office nor organization chart	Bleecker (1994), Galbraith (1995), Hedberg et al. (1997), Bultje and Wijk (1998), DeSanctis and Monge (1998), DeSanctis and Monge (1999), Kemmer and Gillesen (2000), Kasper-Fuehrer and Ashkanasy (2001)
regardless of who “owns” them	
appearing with real physical location	
appearing as single/unified organization	
edgeless, permeable boundaries	
exists electronically/in the internet	

The attributes classified as “goal-oriented” include the purpose respectively the task which drives the VO and plays an important role in the VO (Mowshowitz, 1997a). VOs evolved driven by increasing stress of competition on the global market, increasing complexity in products and processes, escalating costs in R&D, death of resources, altogether supported by new designs and development in ICT (Davidow & Malone, 1992; Snow et al., 1992; Weisenfeld et al., 2001; Picot et al., 2003; Gassmann, 2006). Based on this stream, the VO aimed at the efficient use and was built to be goal-oriented. The numerous aspects in the following table will give insights into relevant aspects as “sharing resources and skills or markets” (Byrne et al., 1993, Vasconcelos et al., 2007). Those aspects could be found within 41.2% of the screened definitions and this demand including this core aspect to the classical characteristics of a VO (Table 6). VOs are built for achieving a common goal.

Table 6 Attributes Classified as “Goal-oriented”

	Corresponding Authors
deliver product/ service in response to customer’s need	
exploit an apparent market opportunity/or utilize an apparent competitive advantage	Byrne et al. (1993), Arnold et al. (1995), Chiesa and Manzini (1997), Bultje and Wijk (1998), Ahuja and Carley (1998), Travica (2005), Sieber and Giese (1998), Cueni and Seiz (1999), Gallivan (2001), Oliveira and Rocha (2001), Kasper-Fuehrer and Ashkanasy (2001), Oliveira and Rocha (2001), Gassmann and Zedtwitz (2003), Picot et al. (2003), Vasconcelos et al. (2007)
provide products and services more independently from time and location than competitors	
share access to one another's market	
access external knowledge and resources	
share costs	
share resources	
share skills	
bound by a long-term common interest or goal	
common goal	
complete production process	
engage in problem solving	
generate and develop successful innovations	
link business goals and needed procedures	
partial missions overlap	
goal to exploit fast-changing opportunities	
shared loyalty	
tasks guided by common purpose	
highly dynamic process	
lateral, dynamic relationships (for coordination)	
opportunistic alliance of core competencies (value-adding partnership)	
goal to share cost, skills, and another’s market	

Summing this up, I think that the attributes of VOs elaborated by DeSanctis and Monge (1999) are still relevant and core characteristics for VO. However, numerous attributes could not be allocated appropriately and I expanded the attributes

- geographically distributed,
- electronically linked,
- functionally or culturally diverse,
- laterally (versus hierarchically) connected developed by DeSanctis and Monge (1999) by adding the following attributes:
- represented as one and
- goal-oriented.

Classifying 87 attributes from 34 different definitions of VO and research of the last 20 years allows the development of these six core characteristics of a VO. This again proves the advance in conceptual research of VOs and the relevance of the topic. These aspects are necessary for properly analyzing VOs.

5. Transferring VO to a Real R&D Collaboration

Due to the growing number of R&D collaboration (for Germany see, e.g., ZEW, 2011) and diversification of partners, suitable management concepts need to be analyzed for their transferability to this field. VOs have been studied for more than 20 years and valuable insights and managerial advice can be adopted. Having developed the six attributes for suitably describing VO, the example in the following section will show that quite a number of R&D collaborations can fulfill the criteria of VO and interesting insights from R&D collaboration will be provided. In this way, the suitability of the elaborated attributes will be tested for a real case in the R&D collaboration context.

5.1 Case Description

This self-observed study includes case data from an exemplary research project which is funded by the German Federal Ministry of Education and Research for five years in a program and researching the replacement of oil in the chemical industry. This case is only one example from a number of initiatives which financed several R&D collaborations for advancing research in special geographic areas or scientific topics. Collaborations had to be formed in advance, applied for funding and contended with other R&D collaborations in the initiatives. Successful research projects are funded by the ministry to support top-level science and research, and this research cooperation includes private companies, too. The exemplary character is based on the fact that several kinds of possible partners (universities, semi-private research organization with non-profit character and private companies) are included in research cooperation except independent individuals. One of the aims of the project is to investigate management principles for these kinds of intersectional and interdisciplinary research cooperation. In addition to governmental funds, the project receives funding from four (one medium-sized and three big) private companies in the lignite and energy sector. Among the recipients, there are two public universities and three research institutes. Two of these three research institutes are embedded in mother associations named Helmholtz and Fraunhofer. Among the universities, one of the two is taking the lead and the administrative hosting of the research project.

Having the characteristics of the equal partners in mind, this research project is a typical case of Triple Helix, too (partners from industry, university and government). A considerable number of people working on the project

are researchers employed by two universities and embedded within specific institutes. A second group contains researchers from research institutes, and the third group includes researchers from the funding companies. Finally, the government is represented through a body responsible for the cooperation which supervises and approves procedures.

The organizational structure and governance system of the project contains the following organizational entities:

- A board, consisting of one representative of each funding company and of the dominating research organization, as well as two professors of the hosting university, who also represent the speakers of the board,
- a project coordinator as central contact person for the whole project (this function implies a connecting position between the board and the researchers, which includes reporting and information sharing with the board as well as sending annual reports to the supervising ministry),
- subgroups and teams of researchers from universities and research institutes referring to the subprojects.

5.2 Application of VO Attributes

The VO attributes developed before are based on literature (including empirical studies) but partially lack testing and application in reality. Hereafter, the elaborated characteristics will be applied on the described case of five-year research cooperation.

Geographically distributed

Due to the fact, that several universities, companies and research institutes are part of the project and as almost all researchers have to stay with their organization (research facility), the partners are geographically distributed in Germany. The maximum distance between partner institutions in this case is about 630 km (within a time zone).

Electronically linked

The geographic distance, mentioned above, requires mainly ICT based communication. In addition to e-mail, telephone, fax and shared databases, some members also use groupware for communication.

Functionally or culturally diverse

The project consists of five different research groups which include researchers from ten different institutes and four different faculties covering, e.g., chemistry, mechanical engineering, geology, material science or business administration. In addition to the disciplinary variety, partners from different universities, companies and semi-private organizations are present in this cooperation and prove the cultural diversity of the team, too.

Laterally (versus hierarchically) connected

Within the project, there is no additional hierarchy to the already existing hierarchy in the respective university or company. All the project partners and institutes or companies are appreciated as equal partners. The board just decides on the strategic direction of the project and the coordinator acts as contact person who consolidates information. The researchers are assigned as specialist to the coordinator but report directly to their line manager. Thus the members and partners are laterally connected.

Represented as One

The present R&D collaboration operates under its own name as an overall organization which is represented through the two speakers and partly the coordinator. At the beginning of the application for funding, corporate identity and corporate design was established among the partners, has been further developed with the official start of research work and is used for regular external communication (homepage, prints, and events) during cooperation.

Goal-oriented

All necessary knowledge and resources were brought together in order to offer a unique contribution. A common research goal which requires specialists with different backgrounds constitute the reason for cooperation. As funding was only granted based on a detailed interdependent plan of all the partners, they all act goal-oriented. Additionally, an attendant form the German Federal Ministry of Education and Research supervises the implementation of the goals, which are by their nature, main interests of the partners.

Through this example of transferring the further developed VO attributes to a real R&D collaboration, the definition has been proven to be applicable to recent cooperation and to be reliable for the R&D context. This case is just a single example but again proves that the VO concept and related topics are still up to date and relevant.

6. Conclusion and Directions for Future Research

Although the concept of VO exists already since the early 1990s, this paper shows that the topic is still up-to-date and ongoing. The analysis of 291 research articles connected to VO and 86 articles on VT provided insights to the actual research situation in this field. Research on VO recently focused on international settings, is conducted from authors of affiliations from 44 different countries (nevertheless mainly in China, USA and Europe), is mainly conceptual and theoretical in its nature and was relevant for 180 different publication channels (journals, conferences, etc.). VT literature is mainly written by authors located in American and European, deals with national and international VT, is much more case-based than VO literature and comprises more different partners (as can be seen with the higher focus on, e.g., university focused papers). The last fact might be explained through the different perspective. As VT research focuses on trust and knowledge exchange, cultural aspects related to the organizational background of the members are an issue and ask for inclusion of different sectors as influence factor. Furthermore, I think that this contribution makes a first step towards building some consistent concept of VO which was missing before (Ratcheva, 2008). The structure of attributes which help defining a VO is based on an analysis of 34 different definitions. Based on the four attributes developed in the inspiring article from DeSanctis and Monge (1999), two further attributes needed to be added, so that, finally, I define a VO as (1) geographically distributed, (2) electronically linked, (3) functionally or culturally diverse, (4) laterally (versus hierarchically) connected, (5) represented as one, and (6) goal-oriented. This clear definition is a first step to help optimizing VOs. Transferring these attributes of a real R&D collaboration in the TH proved the applicability of the VO attributes to R&D collaboration. Of course, this exploratory study does not give a significant empirical proof but it allows drawing first conclusions as it is the first step for optimizing VO to give a clear definition. Facing the escalating number of VOs in R&D, this paper should be seen as an impulse for future research, too, which is needed for elaborating methods regarding how to manage and how to lead (or e-lead (Avolio et al., 2014)) virtual R&D organizations in the TH environment. Expertise from different perspectives needs to be merged in order to find new efficient ways of successfully managing R&D which takes place in VO. Literature offers a variety of success factors for VO (e.g., Cohen & Mankin, 1999) and VT (e.g., Duarte & Snyder, 2006; Nyström & Asproth, 2013) which would be an interesting next step for future studies. Another aspect would be investigating the transferability of success factors. Providing the example of a complex R&D project in the energy sector, this contribution proved that the developed attributes of VO are applicable to R&D collaboration in the TH context. Now this expertise from the VO can be used, applied and transferred to R&D collaboration, so to speak the Triple Helix which is often a VO or operating as VTs.

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Appendix

Table 7 Highest Frequencies of Country of First Author Referred to the Latest Articles on VO

Location of first author	Frequency in % (n = 291)
China	21.6
USA	14.8
Spain	8.2
Italy	6.5
Germany	5.5
UK	4.1
Other	39.3

Table 8 Highest Frequencies of Country of First Author Referred to the Latest Articles on VT

Location of first author	Frequency in % (n = 86)
USA	40.7
UK	8.1
Germany	7.0
Australia	4.7
Taiwan	4.7
Other	34.8

Table 9 Frequencies of Research Methods

Research method	Frequency in % (n = 291) (VO)	Frequency in % (n = 86) (VT)
Conceptual	57.4	47.7
Case-based	29.2	48.8
Review	10.0	3.5
Longitudinal	4.5	n.A.
No abstract available	0.1	n.A.

Table 10 Frequencies of Geographic Focus of the Paper

Geographic focus of the paper	Frequency in % (n = 291) (VO)	Frequency in % (n = 86) (VT)
International	90.8	39.6
National	9.2	36.0
Neutral	---	24.4

Table 11 Frequencies of Sector Focus of the Papers

Sector focus of the paper	Frequency in % (n = 291) (VO)	Frequency in % (n = 86) (VT)
Neutral	66.0	51.2
Company	26.2	26.7
University	6.9	22.1
Other (University+Company, Library, Government)	0.9	---

Table 12 Frequencies of Kind of Publication

Kind of publication	Frequency in % (n = 291) (VO)	Frequency in % (n = 86) (VT)
Proceedings	34.4	29.1
Journals	47.8	60.5
Books/ Book chapters	17.8	10.4